Simulation of black hole physics in Bose Einstein Condensates

Supervisors: Dr A. Retzker & Prof M. B. Plenio

Background – One of the most important discoveries in physics that is still to be verified experimentally is Hawkings prediction that black holes should radiate what is now called Hawking-radiation. One of the most fundamental discoveries that was actually verified with remarkable precision is Bose-Einstein Condensation. In this project you will study the possibility of using the second discovery to verify the first. Although Hawking radiation was never measured it is strongly believed that in the next few years this radiation can be measured in Bose-Einstein condensate systems. Two effects which are strongly related to Hawking radiation are the accelerating mirrors effect and the Unruh effect. In the first case an accelerating mirror was shown to emit thermal radiation that corresponds to the Hawking radiation while in the second Unruh showed that an accelerating observer sees the vacuum as a thermal field, ie filled with photons, with a temperature that corresponds to the Hawking radiation.

In the last few years it was realized that black hole physics can be simulated and probed in Bose-Einstein condensates. The quantum fluctuations of these ultra-cold atoms follow the same equations as quantum fields. Moreover it was understood that it is possible to control these systems in such a way that they emulate the proximity of these fields to strong gravity systems and to black holes.

![FIG. 1: This picture shows the formation of a Bose-Einstein condensate. On the left the distribution is essentially thermal while on the right the atoms have condensed in the ground state.](image)

Project – In this project you will acquire basic aspects of black hole physics and more detailed insights into Bose-Einstein condensates. You will learn the fundamentals of the physics of Bose-Einstein condensates and the various effects that were measured and potentially could be measured in Bose-Einstein condensate. The project will deal with the interplay between the micro and the macro worlds and the incredible manifestation of one within the other. The emphasis of the project will be on the one hand on fundamental physics of quantum mechanical effects in gravity and in cold gases. On the other hand this project will deal with the details of the experimental realization of these effect.

First Year Project – In the first part of this project you will learn the fundamentals of black hole physics and quantum field theory. In the second part you will learn the basic ideas behind cold gases experiments in general and in Bose-Einstein condensation in particular. In the last part you will learn how these ideas can be combined in the same experimental setup.

PhD Project – The range of experimental ideas that can be realized in these systems is enormous. During your PhD you will study possibilities to incorporate the theoretical world with the lab. The project will be conducted in a collaboration with an experimental group of Prof. Joerg Schmiedmayer from Vienna. While the first part of the project will be mainly concentrated on the realization of the Hawking effects and Hawking like effects. The second part of the PhD will be concentrated on constructing new schemes for experiments either for the verification of cosmological or quantum field theory effects or for the study of quantum mechanics in the microscopic world. In the last year we have came up with an idea to measure these related effects in a Bose Einstein Condensate[1]. The first part will be concentrated on the elaboration of this work and from here we will continue to study new effects and exciting physics.